SYSTEM IDENTIFICATION AND PI NEURO-FUZZY CONTROL OF A PNEUMATIC ACTUATOR

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ABSTRACT

Pneumatic actuators have a number of advantages over electric motors, including strength-to-weight ratio, tunable compliance at the mechanism level, robustness, as well as the low price. The Intelligent Pneumatic Actuators (IPA) is a new generation of actuators for research and development (R&D). This research proposes a force model of IPA based on system identification technique. A proportional derivative adaptive neuro fuzzy controller (PI-ANFIS) is presented to validate the new model with real time results. The position IPA is controlled by P-ANFIS controller in MATLAB simulation environment and applied on the real IPA plant. Thereafter the stiffness characteristic of IPA is tested in simulation environment by using two different control techniques based on the proposed position and force control. Finally, a comparison is made between the obtained results and showed that, the objectives were achieved successfully.

ABSTRAK

Sistem pengerak pneumatik mempunyai beberapa kelebihan berbanding dengan motor elektrik, antaranya nisbah kekuatan-berat yang lebih tinggi, kekenyalan boleh ubah, tahan lasak dan kos rendah. ‘Intelligent Pneumatic Actuator’ (IPA) merupakan satu penggerak generasi baru yang digunakan dalam bidang penyelidikan. Dalam kajian ini, satu model penyelakuan bagi penghasilan daya oleh IPA telah dibina dengan teknik SI (system identification) dan satu pengawal 'Proportional Derivative Adaptive Neuro Fuzzy' (PI-ANFIS) telah direka untuk membandingkan model ini dengan sistem sebenar. Satu lagi pengawal P-ANFIS juga telah direka bagi kawalan pergerakan IPA dengan menggunakan perisian simulasi MATLAB dan digunakan pada sistem sebenar. Model-model penyelakuan bagi pergerakan (kedudukan) dan daya ini kemudianya digunakan untuk mengkaji sifat kekenyalan IPA dengan menggunakan perisian MATLAB. Data-data yang telah diperolehi menunjukkan bahawa objektif kajian ini telah dicapai dengan jayanya.

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CHAPTER 1

INTRODUCTION

1.1 Background

Pneumatic systems are extensively used in the automation of production machinery and in the field of automatic controllers. For instance, pneumatic circuits that convert the energy of compressed air into mechanical energy enjoy wide usage, and various types of pneumatic controllers are found in industry. Certain performance characteristics such as fuel consumption, dynamic response and output stiffness can be compared for general types of pneumatic actuators, such as piston-cylinder and rotary types. The final decision on the best type and design configuration for pneumatic actuator can be made only in relation to the requirements of a particular application. The pneumatic actuator has most often been of the piston cylinder type because of its low cost and simplicity [1]. The pneumatic power is converted to straight line reciprocating and rotary motions by pneumatic cylinders and pneumatic motors [2].

Pneumatic systems have many attributes that make them attractive for use in difficult environments: gases are not subjected to the temperature limitations of hydraulic fluids; the actuator exhaust gases need not be collected, so fluid return lines are unnecessary and long term storage is not a problem because pneumatic systems are virtually dry and no organic materials need be used. In addition, the pneumatic actuator has a lower specific weight and a higher power rate (torquesquared to inertia ratio) than an equivalent electromechanical actuator. In some cases, a pneumatic system may provide a significant weight advantage. In short duration missile applications, the weight of a self-contained solid propellant pneumatic servo may be half that of an equivalent self contained hydraulic system. Also the pneumatic actuators have many merits such as easy maintenance and handling, relatively simple technology and low cost, clean, safe and easy to installed [3].

Position control applications have typically used one of two actuator technologies. Hydraulic actuators have speed and force profiles compatible with many industrial processes but can present a number of workplace hazards to personnel. Electromagnetic actuators, on the other hand, are clean and reliable in their operation but often require a mechanical transmission, both to convert high speed and low torque to a more useful combination and to convert rotary motion to linear motion. While linear motors can overcome the need for a transmission, they can be expensive. Pneumatic actuators afford the opportunity to design a positioning system that may be directly coupled with a load like a hydraulic actuator; is clean and reliable like electric motors; and is inexpensive. The challenge to the use of pneumatics is the highly nonlinear dynamics that makes conventional control strategies such as PID (proportional-integral-derivative) ineffective [4].

Intelligent actuator is a new field of research to integrate actuators, micro processors, and various micro sensors. These actuators have communication abilities and local control functions and reduce the number of cables connected, as well as having more delicate and high performance actuator motions [5].

1.2 Problem Statement

The significant of the study refers to the importance of controlling the position, force and stiffness in the pneumatic actuators with the lack of research regarding force and stiffness control. The problem that we aim to solve is demonstrating the intelligent pneumatic actuator ability to have the stiffness characteristic. The difficulties of working on the current system are using ON/OFF valves instead of proportional one and controlling only one chamber. The motivation of the current work is that, there is no exist of force model for the current actuator.

1.3 Research Objectives

The objectives of this study are

- To obtain a linear force model based on system identification (SI) technique.
- To validate the force model with neuro-fuzzy controller in real time.
- To design a neuro-fuzzy controller for position control.
- To simulate the actuator ability to imitate different springs' behaviors by controlling the stiffness.

1.4 Scope of Work

The scope of this research confined to obtain a force model based on systemidentification technique and design an ANFIS controller for force, position and stiffness control. The identification model will be obtained experimentally and the implementation will be carried out using system ID and adaptive neuro-fuzzy inference system (ANFIS) toolboxes in MATLAB. NI-PCI-6221 DAQ will be used to communicate between Simulink and the actuator components. The simulation results will be validated with the real time results.

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